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METHOD OF NON-DISRUPTIVE CAPACITY SCALING FOR A DATA STORAGE LIBRARY

5 ## BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to robotic media storage library systems, and more specifically to a
10 redundant system that includes a plurality of independent robots in the form of robotic pods.

2. Background of the Invention:

The current enterprise class library system contains
15 multiple independent robots for concurrently manipulating multiple media cartridges. The library system comprises an array of media storage cells and media cartridge players. A system of rails is used to guide robotic pods through all of the locations on the array.

20 Scalable library systems typically incorporate additional robotic mechanisms and related electromagnetic hardware to increase the size of a system. Some large systems use "pass through" mechanisms to pass cartridges between individual silos to increase the capacity of the
25 system. Pass through mechanisms are field upgradeable, although the library system must be shut down to allow service personnel inside the enclosure(s) during installation. A silo is a "closed" shape that does not allow for capacity scaling without pass through.

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Therefore it would be desirable to have a method for expanding library system capacity without disrupting normal library operations.

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SUMMARY OF THE INVENTION

The present invention provides a method for scaling
5   a media storage library, wherein the library comprises a
plurality of media storage cells and at least one media
picker robot. The method comprises connecting a new
physical component to a section of the library. Examples
of new components include additional robots, storage cell
10 arrays, media players, as well as connecting a second
adjacent library by means of a pass-through mechanism.
Control software integrates this new physical component
into the function of the library by auditing the content
and function of the new component. During the connection
15 and functional integration of the new component, the rest
of the library continues its current operations. The
method may further comprise defining at least one work
zone within the library, wherein robots do not enter the
work zone but continue to operate in other areas of the
20 library.

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BRIEF DESCRIPTION OF THE DRAWINGS

5   The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in

10 conjunction with the accompanying drawings, wherein:

Figure 1 depicts a perspective pictorial diagram illustrating the architecture of a single library storage array in accordance with the present invention;

Figure 2 depicts a pictorial diagram illustrating

15 the addition of an extension array to an existing library system in accordance with the present invention;

Figure 3 depicts a flowchart illustrating the procedure for adding an extension array to an existing library system in accordance with the present invention;

20 **Figure 4** depicts a pictorial diagram illustrating the addition of a new library system to an existing library system in accordance with the present invention; and

Figure 5 depicts a flowchart illustrating the

25 procedure for adding a new library system to an existing library system in accordance with the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The architecture of the present automated library
array **100** is illustrated in **Figure 1** and contains the
multiple independent robots **102** to enable the library
array **100** to concurrently manipulate multiple media
cartridges **105**. The library array **100** comprises a two-
dimensional array of media cartridge storage cells **103**
and media cartridge players **104** that are mounted in a
frame **101**. A system of rails **121-126** is used to guide
robotic pods **102** through all of the locations in the
array, which eliminates the need for any steering or
guide mechanisms on board the robotic pods **102**, resulting
in a reduction in the mass of the robotic pods **102**. The
rail system **121-126** also constrains the movement of the
robotic pods **102** into horizontal and vertical movements,
thereby simplifying the control algorithms for collision
avoidance that are required by a typical random moveable
object handling system based on horizontal, vertical and
diagonal degrees of freedom. The robotic pods **102** contain
a moveable carriage that is capable of transporting
robotic components, such as media cartridge pickers, bar
code reading devices, and other task oriented sub-units,
on the storage library rail system.

As shown in **Figure 1**, the frame **101** is designed to
receive a plurality of rows **151-154** of media cartridge
storage cells **103**, each of which is designed to house a
single media cartridge **105**. The media cartridge players
104 are shown in an arbitrary location in a horizontal

row **155** at the bottom of the frame **101**, although the
library array **100** can incorporate media cartridge players
104 at any location in the frame **101** to optimize
performance. The robotic pods **102** are attached to the

5 frame **101** via horizontal guide rails **121-126**, which serve
to frame the media cartridge storage cells **103** and media
cartridge players **104** on the top and bottom sides
thereof. **Figure 1** shows an array of media storage cells
103 fully populated with media cartridges **105** of any

10 arbitrary type. The robotic pod guide rails **121-126**
provide support of the robotic pods **102** in the vertical
direction to oppose the force of gravity, and they also
provide a meshing surface of suitable design to impart
traction in the horizontal direction for motive transport

15 of the robotic pods **102**. The robotic pods **102** each
incorporate a drive means for propulsion in the
horizontal direction along the guide rails **121**.

Figure **1** also shows a plurality of vertical elevator
assemblies **131-133** that enable the transfer of the

20 robotic pods **102** in the vertical direction. Multiple
vertical elevator assemblies **131-133** are shown in **Figure
1** to exemplify the extensibility and redundancy of the
invention. Each of the vertical elevator assemblies **131-
133** comprise a set of vertical rails **142** that extend

25 substantially from the top of the frame **101** to the bottom
of the frame **101**. The vertical rails **142** support a
plurality of elevator stations **140**, each of which contain
short horizontal rail segments **141A**, **141B** that are
identical in cross section to the main horizontal guide

30 rails **121-126**. The elevator stations **140** are held in

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suspension by a drive belt **143** which is made to wrap
around a drive pulley attached to a vertical drive motor
113 that is located at the top of each elevator assembly
133. When a vertical displacement is required of any

5   robotic pod **102**, the vertical elevator **140** is scheduled
to move in alignment to the appropriate level of rows
151-155 to allow transfer of the robotic pod **102** onto the
elevator rail section **141A**, **141B** from the pair of
horizontal rails **121-126** that are juxtaposed and abutting

10 to the elevator rails **141A**, **141B**. Once the robotic pod
102 is located on the elevator station **140**, the drive
motor **113** is activated to transport the robotic pod **102**
to a selected one of rows **151-155** and thence moves on to
the pair of horizontal rails **121-126** that correspond to

15 the selected row. Elevator assemblies **131-133** can carry
more than one robotic pod **102** at a time by adding
elevator platforms **140** to the elevator assemblies **131-133**
or by extending the elevator platform length to
accommodate multiple robotic pods **102** on a single

20 elevator station **140**.

Referring to **Figure 2**, a pictorial diagram
illustrating the addition of an extension array to an
existing library system is depicted in accordance with
the present invention. The library system **210** depicted

25 in **Figures 2A-2D** is comprised of several library arrays,
similar to array **100** in **Figure 1**, which are arranged in
banks. The track type architecture used with the storage
arrays (depicted in **Figure 1**) allows the arrays to be
connected within a single library system, wherein

30 "roaming" robots can move between arrays by following

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connecting tracks, which trace cartridge locations and
tape drives within the library system.

    Figure 3 depicts a flowchart illustrating the
procedure for adding an extension array to an existing
5   library system. The procedure begins by selecting, via
an operator control panel, the desired capacity scaling
method, which in the present example is the addition of
an extension array **220** onto an existing library system
210 (step **301**). The selection causes the control
10 software to move robots away from the end of the rail
location where the extension **220** is being added, and
establishes the working space as a "keep-out" zone for
the robots (step **302**). In this way, robots within the
existing library system **210** can continue to operate in
15 other areas of the library, without interfering with the
addition of the extension array **220**. The operator panel
is then used to set the relevant service door to an
"open-eminent" state, thus alerting the control software
to clear the robots from the work area (step **303**).

20   A door key is then used to unlock and open the
service door (step **304**). The front cover assembly **211** is
removed from the end of the library system **210** where the
extension **220** is to be added (step **305**), and the
extension array **220** is added to the existing library
25 system **210** (step **306**). The robot guide rail segments of
the extension array, e.g., rail **230**, are then fit to the
guide rails on the existing library, e.g., rail **240**, thus
connecting power to all segments (step **307**). A front
cover assembly **221** is placed onto the end of the
30 extension array **220** (step **308**). Additional robots can

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then be added as needed before the service door is closed (step **309**).

After the physical components have been connected and the service doors have been closed, the operator
5   panel is used to notify the control software to initiate calibration and audit routine to bring the extension array on line with the preexisting library system (step **310**).

When integrating new silos and arrays into an
10 expansionable library system, specific control algorithms are used to facilitate seamless integration. These control algorithms allow the library system to automatically detect new components and determine which resources are available to the system at any time. The
15 algorithms may rely on meta data, which is an inventory of resources available to an array at any given time and is maintained on a micro basis (short time periods). Examples of meta data include: what data storage devices are located within an array; where the storage arrays are
20 located; and how many robots are presently on the array and where they are located, which can change every few fractions of a second as robots move from one array to another. When adding new components to a library system, it is important to merge and integrate the meta data from
25 the different components. When a component is removed, the meta data is uncoupled. Meta data can be stored in NV-RAM, on a hard drive, or any other type of non-volatile memory storage within the arrays, which can hold its memory without power.

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By implementing the control algorithms described above, there is no need to shut down the library system **210** in order to add new physical components (i.e. extension **220**). The host system **210** will automatically

5   detect these new components and incorporate their function and contents into ongoing system operations.

Referring to **Figure 4**, a pictorial diagram illustrating the addition of a new library system to an existing library system is depicted in accordance with

10   the present invention. **Figure 5** depicts a flowchart illustrating the procedure for adding the new library system. The procedure begins by selecting, via an operator control panel, the desired capacity scaling method, which in the present example is the addition of

15   an adjacent library **410** with a pass-through mechanism **420** (step **501**). The selection causes the control software to move robots away from the end of the rail location where the adjacent library **410** is to be connected, and establishes the working space as a "keep-out" zone for

20   the robots (step **502**). In this way, robots within the existing library system **400** can continue to operate in other areas of the library, without interfering with the connection of the adjacent library **410** and the installation of the pass-through mechanism **420**. The new

25   library system **410** is then placed next to the original existing library **400** (step **503**).

The operator panel is then used to set the relevant service door **402** to an "open-eminent" state, thus alerting the control software to clear the robots from

30   the work area (step **504**). A door key is then used to

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unlock and open the service door where the pass-through mechanism is going to be placed between the library systems (step **505**).

The operator should remove any robots from the work area where the pass-through mechanism is to be installed (step **506**). The pass-through cover plates **401** and **411** are removed from the side walls of the libraries, thereby allowing the pass-through mechanism **420** access to both library systems **400** and **401** (step **507**), and the pass-through mechanism **420** is installed by means of the service doors **402** and **412** of either library (step **508**).

The pass-through mechanism **420** allows cartridges to be passed between the adjacent libraries **400** and **410** by means of a bucket **421**, which is driven about a pivot axis **423** by a motor **422**.

The power and control circuits of the new adjacent library **410** are then connected to the cable harness of the mother library **400** (step **509**). Unlike the addition of an extension array, the connection of adjacent libraries does not require the operator to fit guide rail segments between the adjacent libraries. This is because each library is physically self-contained, except for the pass-through mechanism.

Once the libraries **400** and **410** are connected, robots are replaced and/or added as needed and the service doors **402** and **412** are closed (step **510**). The operator control panel is used to notify the control software to initiate calibration and audit routine to bring the new adjacent library **410** on line with the original mother library system **400** (step **511**).

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As with addition of extension arrays, by implementing the control algorithms described above, there is no need to shut down the mother library system **400** in order to add new library **410**. The host system **400**

5 will automatically detect the new library **410** and incorporate its function and contents into ongoing system operations.

The description of the present invention has been presented for purposes of illustration and description,

10 and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention,

15 the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.